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Revisiting the Internet Routers' Buffers Sizing Problem

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ABSTRACT

The problem of appropriately sizing routers' buffers has been a research issue which has elicited considerable interests for more than 30 years now. The question that has been so much debated is: How large should these buffers be? Three main buffers' sizing rules exist in the literature, which are: Bandwidth-Delay Product (BDP), small-buffers' and the tiny-buffers' rules. But researchers are largely agreed that, the BDP formula specifies unrealistically large buffers; while the generic utility of the small and tiny buffers' formulas have been questioned by most researchers. Some researchers have even opined that, deriving a single universal formula for dimensioning the buffers may not be possible: But, the congestion problem of data networks has largely been linked to inappropriately sized buffers. The main objective of this paper is to report the application, in the context of Internetworking Protocol (IP) networks, of a novel formula that was derived in a previously published paper; which can be used to appropriately specify these buffers. Additionally, we argue that, the formula is indeed a unique solution of the buffers' sizing problem. The justification for this position is premised on the fact that, the formula may specify what we refer to as very-tiny buffers', in addition to specifying literature's tiny buffers' capacities - a clear validation of the widely-held view that, the BDP formula specifies unrealistically large buffers. The reported formula however, has a huge advantage over literature's tiny and small buffers' formulas; as, it is 'application-generic', unlike literature's tiny and small buffers' formulas

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1. INTRODUCTION

The buffers for holding traffic at the interfaces of routers and switches constitute a central element of packet-switched networks. The problem of appropriately sizing the buffers' has been an open research issue, which has elicited considerable interests in the last couple of years; and has witnessed lots of debates, that centres on: How large should these buffers be? [1-8] The buffers sizing problem has been considered a black art [9], as a result of its complexity; being governed by several factors, such as, TCP flows' window sizes, the flows' RTTs (Round Trip Times), and, packets' loss-rates [10 - 11]. Importantly, network and switch designers encounter a buffer-size/bandwidth trade-off problem; as the designers can choose between two methods to deal with temporal increase in network traffic: they can either increase the buffer sizes of switches and routers, or, increase the link bandwidth; but little is known about the trade-offs between these two methods [4]. However, while large buffers can absorb long traffic bursts, a large link bandwidth allows faster draining of the buffers, and more frequent pausing of the transmission on the incoming link, thus resulting in the need for small buffers' sizes [4]. Generally, increasing buffer capacity tends to increase link utilization, decrease loss rates [9, 12], but at the cost of increased RTTs, as a result of increases in queuing delays [12]. Moreover, the buffers of the nodal devices (switches and routers) that are installed in switched networks contribute to the costs' and power consumption of these devices, and hence, of the networks: the larger the buffers, the more the costs and power consumption of the devices and the associated networks, and vice-versa. A fundamental question, therefore, is: What is the minimum buffer requirement of a network link, given the constraints on minimum link utilization, maximum loss rate, and minimum queuing delay? [7]. It is our view that, this last constraint should be maximum queuing delay, and not, minimum queuing delay. Surprisingly, the answer to this question is not well understood, and several answers have been quoted [7]. This position is reinforced by the researchers in [13], who asserts that: 'the question of how much buffering does a given Internet router interface need has received hugely different answers in the last 15-20 years; with answers that include, a BDP amount of buffers; buffers for a few dozen packets; a multiple of the number of large TCP flows in a link. The researchers contend further that: it cannot be that all these answers are correct; and that, it is clear that a crucial piece of understanding of the problem is being missed, despite the apparent simplicity of the question that needed to be answered. Nevertheless, the buffers in routers and switches interfaces needed to be sized correctly, in order not to introduce too much delays or too much lag, for transport protocols to adapt to sustained network-related congestion conditions [14]. Therefore, the purpose of this paper is to report the application, in the context of IP packet-switched networks (utilizing IP packets) of the novel, generic, closed-form, and practically applicable formula that was derived in [15] – the illustrative example that was given in [15] was done in the context of the Ethernet frame. The formula in [15] can be used to optimally compute the buffer-sizes that should be provisioned in the switches and routers that are the nodal devices of these classes of networks. Additionally, we intend to reiterate in this paper the fact that, the formula which was reported in [15] is indeed, a practical solution of the Internet routers' buffers' sizing problem.

2. Main Approaches to Sizing Internet Routers' Buffers

There are three approaches currently recognized in literature for sizing switches and routers buffers, these are; the BDP rule, given as: $B = C \times RTT$, standardly being used by routers' manufacturers for sizing routers' buffers; here, B = buffer size in bits, RTT = the average Round-Trip-Time of a flow through the router, in seconds; also defined as, the time interval between when a packet is sent out by a source and when an acknowledgement is received from the destination; C (in bits/sec.) = bits' issuing capacity of the router's output interface. This rule which is attributed to the researchers in [16], leads to specifying Gigabytes buffers' (specifically, approximately 1.25 Gigabytes) sizes for routers, and was obtained in 1994 using at most 8- TCP flows on a 40 Mbps core link [5]. The second approach to sizing buffers considers situations where there are N-TCP long-lived flows that share a bottleneck link at the core of the Internet, with no synchronization between the flows. The model is given as: $B = RTT \times \frac{C}{\sqrt{N}}$, and specifies about 12.5 MB of buffer for a core router carrying 10,000 TCP flows; it also assures a near 100% link utilization; and, it is referred to as the small-buffers' or Megabytes buffers model: the researchers in [4] first suggested it. The third approach known as the tiny-buffers' model recommends buffers' sizes that can hold between 20 to 50 packets; that is, buffers with sizes $B = O(\log W)$ bits; where, W = the congestion window size of a source. The congestion window size determines a source's packets' emitting rate, and, is effectively the quantity of bits transmitted by the source during each RTT. The tiny-buffers' model results in kilobytes of routers' buffers, with an 80% to 90% link utilization; and it assumes that the network is overprovisioned, and that, the TCP sources are not very bursty: a situation that can be achieved if a source's flow is paced, or, if the access link or access network is of small bandwidth compared to the core link or network [6]. This model is generally attributed to the researchers in [9, 17].

3. The Buffers’ Sizing Problem as an Unresolved Issue in the Literature

From literature evidence, it can be inferred that the general consensus amongst leading researchers is that, the routers buffers’ sizing problem has not been agreeably solved by researchers. Assertions that were made by eminent researchers at a 2019 Workshop on buffers’ sizing which was held at Stanford University, USA, buttress this point-of-view. For example, at the Workshop, Mckeown [1] asked the Question: Does a routers’ buffers sizing problem actually exist? This researcher went on to aver that: Some network operators deploy switches and routers with buffers’ sizes which, the buffer bloat argument regards as overly generous; whereas, other network operators deploy switches and routers with scant buffers - an approach that may result in data sources being starved, while at the same time, allowing the existence of idle network capacity. This researcher further asked the following very probing question: How big should buffers be? Put differently, how small should switches and routers buffers be provisioned in a network environment that is getting increasingly larger and faster, and still achieve efficient and fair outcomes in a variety of deployment scenarios? According to the researchers in [18], how large should switches and routers buffers be in a given network is yet to be properly understood. Moreover, the BDP rule has been challenged by not a few researchers, for example, the researchers in [4, 8]. It has also been averred by the researchers in [5] that, in experimental studies carried out to determine the appropriate buffers’ sizes for routers in the Internet, using both the tiny and small-buffers’ models, researchers have observed that, the small-buffers’ model ‘appears’ to hold in both the laboratory and operational network environment.

According to Vu-Brugier et al. [19], the credibility of the postulations, inferences, and results of several works on routers’ buffers sizing in literature is doubtful; furthermore, these researchers contend that, their measurements on a production link confirms that traffic patterns do indeed change significantly over time, that this immediately calls to question the utility of the fixed buffer sizing strategies in real communication networks, that this potentially motivates adaptive approaches to buffer sizing, and that, ADT (Adaptive or Active Drop Tail) algorithm can be used to adaptively tune required buffer sizes. In the same vein, Zhang and Loguinov [20] asserts that, most existing criteria (for example, [4] and [8]) for sizing router buffers rely on an explicit formulation of the relationship between buffer size and the characteristics of Internet traffic, which they contend, is a non-trivial, if not an impossible task; given that, the number of flows, their individual RTTs, and congestion control methods, as well as flow responsiveness, are unknown. They therefore, adopted a completely different approach that uses control-theoretic-based buffer-sizes’ tuning, in response to traffic dynamics, called ABS (Adaptive Buffer Sizing), which dynamically adjust buffer sizes. However, we assert here that, this view by these researchers is somehow, missing the point; in this context, we ask the following question: are routers’ buffers sizes determined during the operations of networks, or when the routers to be deployed in the networks are being specified during network design? This question put differently is: Should we say because of the time-varying nature of networks’ traffic, at the point of design and then installation, the routers should be without buffers? Then, what routers’ buffers would be adaptively assigned when the network is in operation? According to the researchers in [13] it may not be possible to derive a single universal formula for dimensioning buffers at any router’s interface in a network; instead, an administrator of a network should decide the buffer capacity by taking into account, factors such as flow-size distribution, nature of TCP traffic, output-input capacity rates, and other factors. The preceding point-of-view conclusively highlights further, the dilemma as rightly pointed out by Mckeown in [1], and confusion that has surrounded the results of the various researches on Internet routers/switches buffers’ sizing and provisioning, that has been reported in literature. How will it be possible for a network administrator, to consider these indicated intricate factors, which in most cases, are abstract, and are physically and practically indeterminable, and then use them to fix capacities values for routers buffers? The Internet routers’ buffers’ sizing problem can indeed be considered a black art, as observed by the researchers in [8]. Ending this ‘black art’ syndrome is one motivating and influencing factor of our research. It is our considered view that, the essence of the various efforts and works on the buffers’ sizing problem is not just to engage in fanciful theoretical excursions, laced with much elegant mathematical formulations, but to come up with practically utilizable formula(s) for solving this problem.

4. Networks' Topologies Approach to Sizing Internet Routers and Switches Buffers

It has been recommended by the researchers in [21] that, through engineering, it may be possible to use small buffers in routers, even upon contrary technical reports. The researchers in [21-22] advocate that, Internet routers' buffers studies' should be done putting into consideration the network topologies. Zhang and Loguinov [20] have also opined that, routers' buffers sizes are closely linked to the following critical performance metrics: packets' loss rates, end-to-end delay, and link utilization. Our approach therefore, takes a network engineering point-of-view as canvased by the researchers in [21]; adopts a network topology (no matter the complexity of the topology) approach that is recommended by the researchers in [21-22]; and is based on the concept of 'maximum end-to-end queuing delays' constraints - supported by the researchers in [8, 20]. The approach which is based on the concept of Traffic Pipes which was formulated and reported in [15] was used to derive (1) as our formula for computing the Minimum Nodal Buffer Capacity (MNBC) that should be provisioned in any node N_x (in order to service node N_x without dropping traffic, and at full links' utilization) - the derivation is also explained in [15]. Node N_x would usually be the centre node in any star subnetwork, which would usually be extracted from any switched MAN/WAN (this computation of MNBC for any node N_x shall be illustrated shortly, but the full explanation and justifications for the approach can be found in [15]).

$$\text{MNBC (bits)} = \frac{(n^2 - n)(2\sigma + 5L)}{4}$$

(1

In (1), n = number of nodes in the star subnetwork, σ = the largest amount of burst traffic in bits that can arrive at an input port of node N_x, L = the maximum length, in bits of a PDU (Protocol Data Unit); for example, IP Packet, in IP packet switched networks, Cell, in ATM (Asynchronous Transfer Mode) networks. We call Eq. (1) the Eyinagho-Falaki formula for specifying the buffer capacities of nodes (routers and switches) in any IP packet-switched MAN/WAN, including the Internet. A major advantage of (1) is that, instead of pacing traffic at the ingress of a network, as suggested by some researchers (for example [6], [10], [17]), or using access links that are of much smaller capacities than the capacities of core links as suggested by some researchers (for example, [7, 10-11]), the ingress node (for example, ingress router) of a network can be directly and simply configured by the network administrator to accept burst traffic, which are inevitable in today's Internet, but to shape any burst traffic with σ greater than the value that is configured to be utilized in (1).

5. Results and Discussions

Let us now illustrate the practical application of (1) by utilizing it to compute the MNBCs for typical subnets' nodes, and see how the values obtained compares with values that have been mentioned in literature: that is, the baselines used for the comparison are the buffers' capacities' values specified by the routers' buffers-sizing formulas in literature. To calculate MNBCs using (1), we need values of L, σ and n. There are different types of PDUs flowing in the Internet, but the most common one is the IP packet, illustrated in Fig. 1. We will use the value of L from this figure, which is, 65,536 bytes. We will assume values of σ to be various numbers of Ls; that is, the different burst sizes should be equal to different numbers of packets (frames) arriving to the node (switch or router) in a burst.

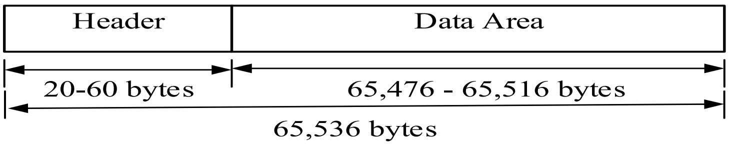


Figure 1 Basic Structure of an IP Packet

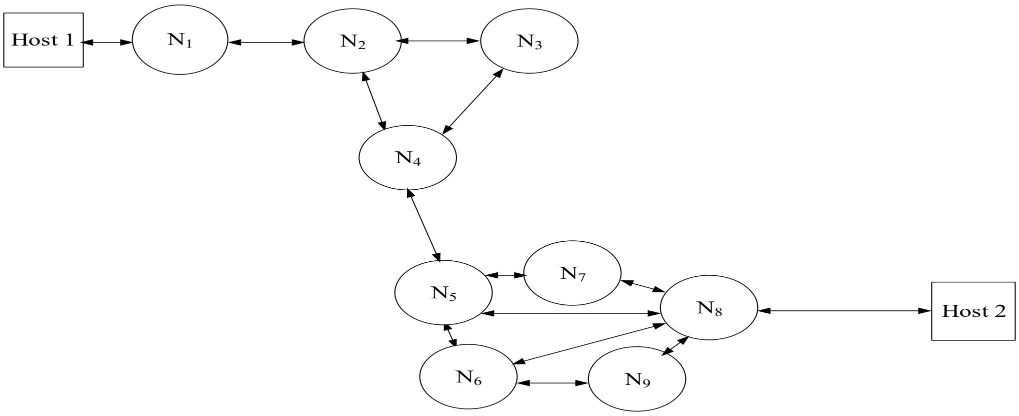
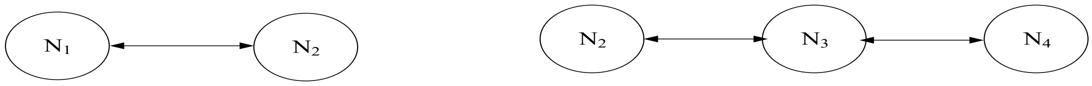


Figure 2 A typical interconnected subnets in the Internet

Since a typical subnetwork will consist of, as a minimum, two (2) nodes (as a node standing alone does not constitute a network – it must in the context of guided media-linked Internet, be connected to at least one other node) and a maximum, which will depend on the structure of the subnetwork, we present in Table 1, specified buffer capacities for star-point node, for subnetworks consisting of two (2) to five (5) nodes (a single node situation is also tabulated in order to reinforce the remark that was made in the previous sentence). Subnetworks with more than five (5) nodes could be treated in a similar fashion by extending Table 1 further, horizontally: the table can also be extended vertically for various other values of σ (= xL). Shown illustrated in Fig. 2 is a typical switched network, which may be a part of the Internet. Although, a 2-nodes' network is not a star network by its nature, we just assume that, any of the two nodes for which we desire to compute the MNBC is taken to be the node N_x. Note that, End Devices like Personal Computers, Server Machines, Printers (for example, Print Servers), are not regarded as nodes in our solution perspective, they are regarded as Host Equipment; it is only Switching Devices like switches, routers that are regarded as nodes. Therefore, in Fig. 2, Host 1 and Host 2 are not nodes. Shown illustrated in Fig. 3 are typical (a) 2-nodes', (b) 3-nodes', (c) 4-nodes', and (d) 5-nodes' subnetworks that were extracted from Fig. 2. MNBC in bits in Eq. (1) can be converted to MNBC in bytes, as indicated by Eq. (2); and reflected in Table 1.

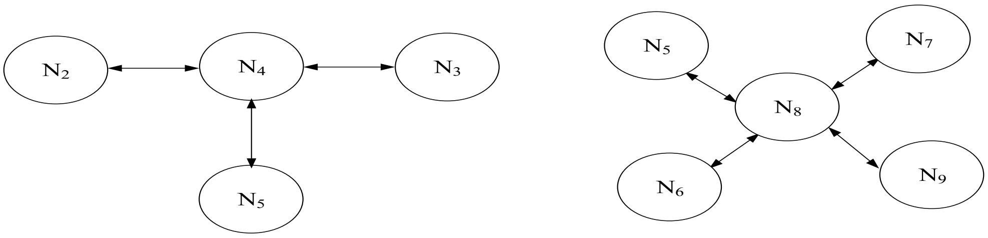
$$\text{MNBC (bytes)} = \left[\frac{5L(n^2-n)}{32}+\frac{\sigma(n^2-n)}{16}\right] = (0.1563L+0.0625\sigma)(n^2-n) \qquad (2)$$

In summary, the approach for specifying the buffer (memory) capacity to be provisioned in any router/switch in the Internet as explained in [15] simply entails, extracting the subnet nodes (routers and/or layer-3 switches) in the Internet that have immediate links to the node (router/switch) of interest. The node for which buffer capacity is to be specified is then indicated as node N_x, and the number of nodes in the subnet is indicated as n. The maximum length, L (in bits) of the PDU of interest is then calculated; for example, the maximum length of IP packet is 524,288 bits, that of the Ethernet frame (applicable to, for example, Metro Ethernet networks) is12,240 bits. A maximum burst size, σ (in bits) of bursty traffic that is likely to traverse the network is then determined. Since no method is currently available in the literature for determining the parameter σ, a particular number of Ls can be assumed for this parameter, while ensuring that, routers/switches are configured to shape traffic traversing the network (token bucket is the most widely used shapper), so that the traversing traffic's σ conforms to specified σ. Lastly, Eq. (1) is utilized to determine the MNBC for the node, N_x of interest.



(a) A 2-Nodes Sub-Network, with N_1 taken as Node N_x, that is, the star-point

(b) A 3-Nodes Sub-Network, with N_3 taken as Node N_x, that is, the star-point



(c) A 4-Nodes Sub-Network, with N_4 taken as Node N_x, that is, the star-point

(d) A 5-Nodes Sub-Network, with N_8 taken as Node N_x, that is, the star-point

Figure 3 Typical (a) 2-nodes, (b) 3-nodes, (c) 4-nodes, and (d) 5-nodes subnetworks extracted from Fig. 2

Table 1: Computed MNBCs for Star-point Nodes for Subnets with 1to5 Nodes for some σ = xLs

Maximum Number of IP Packets in a Burst (σ = xL)	Formula for MNBC (in bytes), for Subnetwork star-point Node (Router or Switch)	Number of Nodes in Subnetwork				
x		1	2	3	4	5
0 (σ = 0)	$0.1563L(n^2 - n)$ Bytes	0MB	0.1638MB	0.4915MB	0.9830MB	1.6384MB
	$0.0625\sigma(n^2 - n)$ Bytes	0MB	0MB	0MB	0MB	0MB
	$(0.1563L+0.0625\sigma)(n^2 - n)$Bytes	0MB	0.1638MB	0.4915MB	0.9830MB	1.6384MB
1 (σ = L)	$0.1563L(n^2 - n)$ Bytes	0MB	0.1638MB	0.4915MB	0.9830MB	1.6384MB
	$0.0625\sigma(n^2 - n)$ Bytes	0MB	0.0082MB	0.0246MB	0.0492MB	0.0819MB
	$(0.1563L+0.0625\sigma)(n^2 - n)$Bytes	0MB	0.1720MB	0.5161MB	1.0322MB	1.7203MB
2 (σ = 2L)	$0.1563L(n^2 - n)$ Bytes	0MB	0.1638MB	0.4915MB	0.9830MB	1.6384MB
	$0.0625\sigma(n^2 - n)$ Bytes	0MB	0.0164MB	0.0492MB	0.0983MB	0.1638MB
	$(0.1563L+0.0625\sigma)(n^2 - n)$Bytes	0MB	0.1802MB	0.5407MB	1.0813MB	1.8022MB
3 (σ = 3L)	$0.1563L(n^2 - n)$ Bytes	0MB	0.1638MB	0.4915MB	0.9830MB	1.6384MB
	$0.0625\sigma(n^2 - n)$ Bytes	0MB	0.0246MB	0.0737MB	0.1475MB	0.2458MB
	$(0.1563L+0.0625\sigma)(n^2 - n)$Bytes	0MB	0.1884MB	0.5652MB	1.1305MB	1.8841MB
4 (σ = 4L)	$0.1563L(n^2 - n)$ Bytes	0MB	0.1638MB	0.4915MB	0.9830MB	1.6384MB
	$0.0625\sigma(n^2 - n)$ Bytes	0MB	0.0328MB	0.0983MB	0.1966MB	0.3277MB
	$(0.1563L+0.0625\sigma)(n^2 - n)$Bytes	0MB	0.1966MB	0.5898MB	1.1796MB	1.9661MB
5 (σ = 5L)	$0.1563L(n^2 - n)$ Bytes	0MB	0.1638MB	0.4915MB	0.9830MB	1.6384MB
	$0.0625\sigma(n^2 - n)$ Bytes	0MB	0.0410MB	0.1230MB	0.2458MB	0.4096MB
	$(0.1563L+0.0625\sigma)(n^2 - n)$Bytes	0MB	0.2048MB	0.6144MB	1.2288MB	2.0480MB

5.1 Discussion of Table 1

From Table 1, it can be seen that, the formula (Eq. (1) or (2)) results in buffers capacities' specifications that range between what we may term 'very-tiny buffer', for situations where σ is zero or very small, and the subnetwork has the topology that is shown in Fig. 3(a), in which only one source of bursty traffic to the node of interest exist; and tiny buffer, for situations where σ becomes large and/or the number of nodes in the subnetwork for which we desire to specify the buffer capacity for the star-point node is no longer small. That is, as the quantity of burst traffic allowed into a network increases, and/or the number of nodes in the desired subnetwork increases, the specified buffers' capacities increases. For example, consider Figs. 3(a) and 3(d) (represented by entries in the second and fifth sub-columns, under the column heading 'Number of Nodes in Subnetworks'), when σ = 0 (zero burst traffic), 0.1638 MB (2.5 IP packets or very tiny buffer) is specified for the node of interest for a 2-nodes (Fig. 3(a)) subnet, and 1.6384 MB (25 IP packets or tiny buffer) is specified for the node of interest for a 5-nodes subnet (Fig. 3(d)).

When σ = L (burst taken as one IP packet), 0.1720 MB (2.6 IP packets or very tiny buffer) is specified for the node of interest, for a 2-nodes subnet, and 1.7203 MB (26 IP packets or tiny buffer) is specified for the node of interest, for a 5-nodes subnet; when σ = 2L (burst taken as two IP packets), 0.1802 MB (2.8 IP packets or very tiny buffer) is specified for the node of interest, for a 2-nodes subnet, and 1.8022 MB (28 IP packets or tiny buffer) is specified for the node of interest, for a 5-nodes subnet; when σ = 3L (burst taken as three IP packets), 0.1884 MB (2.9 IP packets or very tiny buffer) is specified for the node of interest, for a 2-nodes subnet, and 1.8841 MB (29 IP packets or tiny buffer) is specified for the node of interest, for a 5-nodes subnet; when σ = 4L (burst taken as four IP packets), 0.1966 MB (3 IP packets or very tiny buffer) is specified for the node of interest, for a 2-nodes subnet, and 1.9661 MB (30 IP packets or tiny buffer) is specified for the node of interest, for a 5-nodes subnet; when σ = 5L (burst taken as five IP packets), 0.2048 MB (3.1 IP packets or very tiny buffer) is specified for the node of interest, for a 2-nodes subnet (this situation whereby, for a 2-nodes subnet, 3.1 IP packets' buffer capacity is specified when a burst of 5 IP packets is allowed to arrive at the input of the nodal device is very interesting, as it simply means that, with only a single node connected to the node of interest, there are no cross-traffic, and the node simply issues out (transmits) the traffic as it arrives from the other node to which it is connected, if it does not go on vacation – that is, stop transmitting traffic, despite the availability of traffic to transmit); and 2.0480 MB (31 IP packets or tiny buffer) is specified for the node of interest, for a 5-nodes subnet. From the preceding information, we are obviously justified in proposing, in addition to the tiny-buffer sizing rule in literature (20 to 50 packets), the 'very-tiny' buffers sizing (< 20 packets) concept. The above quantities were obtained from situations where the traffic entering the subnetwork is not bursty (σ = 0), or not very bursty (σ = L, 2L, 3L, 4L, and 5L); other burst sizes (6L, 7L, 8L, …), and/or for larger-sized subnetworks, the specified nodal buffers' capacities becomes proportionally larger; that is, as σ (maximum size of traffic burst that is allowed into the network) becomes larger and/or the size of a subnetwork becomes larger, the buffer capacity that would be specified for any node N_x grows proportionally larger. One point that is of much significance here can be discerned by taking a look at the values that are tabulated in Table 1, in comparison with the small-buffers' specification in the literature. Literature's small-buffers' specification is ≈ 12.5 MB. From the values shown in Table 1, for the buffer capacity specified with (1) or (2) to become =12.5 MB, will require quite a large value of σ (possibly, several hundreds of IP packets in a burst of traffic) and/or quite a large subnetwork (a large number of nodal devices - switches/routers are connected to the nodal device (switch/router) - node N_x, for which we desire to specify buffer capacity for loss-less operation). This clearly indicates that, the tiny buffers' rule in the literature should be the correct rule that should be used to specify buffers' capacities, and not the BDP rule or the small buffers' rule. But the problem with literature's tiny buffers' rule is that, it is not a closed-form and generic formula, unlike the formula that was derived in [15], and stated above as Eq. (1) – answer in bits and Eq. (2) – answer in bytes. One of the conclusions that was arrived at by the researchers in [18] after their Buffer Sizing Experiments at Facebook, is put as follows: With regard to the following performance metrics: flow completion time, latency, link utilization, and packets' drop rates, our observations suggest that, reducing buffers from millions of packets to a few thousand, and even a few hundred packets, does not lead to a general degradation in network performance. This observation by these researchers no doubt, gives fillip to the computed values shown in Table 1. But which formula should be used for this suggested reduction? Non was suggested by these researchers: this is where the importance of Eqs. (1) and (2) of this paper is apparent.

6. Conclusion and Further Research Work

Mckeown in [1] asserts that, to choose a buffer size is an inherently complicated thing; he also opined that, so far, there has been some measurements and theory, but very little consensus. And the researchers in [13] have contended that, it may not be possible to derive a single universal formula for dimensioning buffers at any router's interface in a network. But we believe that, the formula that was derived and reported in [15] and that is applied to a hypothetical network in this paper may be the solution to the routers/switch's buffers' sizing problem. We have shown this by the buffers' capacities specified values that are tabulated in Table 1 and by the discussions in Section 5.1. The purpose of this paper therefore, is to draw the attention of researchers to this fact. We are currently looking at the special situation that relates to the sluggishness problem during periods of heavy network usage, as it relates to switched Local Area Networks (switched LANs) and switched Campus Area Networks (switched CANs), which has been variously reported in the literature by several researchers; a problem which we believe has something to do with appropriately sizing the buffers of the switches and routers that are installed in this class of networks.

REFERENCES

[1]. 1.Mckeown, N.: "Introduction to Call for Papers by Program Committee Chair," 2019 Workshop on Buffer Sizing, Stanford University, Palo Alto CA USA, December 2-3, 2019

[2]. Wang, H.: "Trade-Off Queuing Delay and Link Utilization for Solving Bufferbloat'" ICT Express, vol. 6, pp. 269-272, 2020

[3]. Shipner, A., Zahavi, E., Rottenstraich, O.: "The Buffer Size Vs Link Bandwidth Trade-off in Lossless Networks," IEEE Hot Interconnects: Symposium on High Performance Internetworks, Mountain View, CA, August, 2014

[4]. Appenzeller, G., Keslassy, I., Mckeown, N.: "Sizing Router Buffers," Proceedings of the ACM SIGCOMM, New York, USA, pp. 281-292, Sept., 2004

[5]. Arun, V., Vijay, S., Thottan, M.: "Perspectives on Router Buffer Sizing: Recent Results and Open Problems," ACM SIGCOMM Computer Communication Review, vol. 39, no. 2, pp. 34-39, April 2009.

[6]. Beheshti, N., Ganjali, Y., Goal, A., Mckeown, N.: "Obtaining High Throughput in Networks with Tiny Buffers," In IEEE IWQoS, Netherlands, 2008

[7]. 7.Beheshti, N., Ganjali, Y., Rajaduray, R., Blumenthal, D., Mckeown, N.: "Buffer Sizing in all-optical Packet Switches," Proceedings OFC/NFOEC, March, 2006.

[8]. Dhamdhere, A., Jiang, H., Dovrolis, C.: "Buffer Sizing for Congested Internet Links," Proceedings of the Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2005), Miami, Florida, USA, pp. 1072-1083, March, 2005

[9]. Elsaadany, A., Singhal, M., Ming, L. T.: "Performance Study of Buffering within Switches in Local Area Networks," Computer Communications (Special Issue on Computer Communications and Networks), pp. 659-667, July 1996

[10]. Enachescu, M., Ganjali, Y., Goal, A., Mckeown, N., Roughgarden, T.: "Routers with Very Small Buffers," Proceedings of the IEEE INFOCOM'06, Barcelona, Spain, pp. 1-11, April, 2006

[11]. Enachescu, M., Ganjali, Y., Goal, A., Mckeown, N., Roughgarden, T.: "part 111, Routers with Very Small Buffers," ACM/SIGCOMM Computer Communications Review, vol. 35, no. 3, pp. 83-90, July, 2005

[12]. Wischik, D.: "Fairness, QoS, and Buffer Sizing," ACM SIGCOMM Computer Communications Review, vol. 36, no. 1, January, 2006

[13]. Prasad, R. S., Dovrolis, C., Thottan, M.: "Router Buffer Sizing Revisited: The Role of Output/Input Capacity Ratio,"Proceedings ACM/SIGCOMM CoNEXT, USA, Dec. 2007

[14]. Extreme Networks, "Congestion Management and Buffering in Data Center Networks: A Solution White Paper," http://www.ExtremeNetworks.com/contact, 2014 (10-10-2018)

[15]. Eyinagho, M. O., Falaki, S. O.: "Appropriate Buffers' Sizes for Internet Nodal Devices: A Networks Topologies'- Based Solution," International Journal of Communication Systems, vol.

33, no. 8, 2020 16. Villamizar, C., Song, C.: “High Performance TCP in ANSNet,” ACM Computer Communications Review, vol. 24, no. 5, pp. 45-60, October, 1994

[16]. Raina, G., Towslay, D., Wischik, D.: “Part II: Control Theory for Buffer Sizing,” ACM/SIGCCOMM Computer Communications Review, vol. 35, no. 2, pp. 79-82, July 2005

[17]. Beheshti, N., Lapukhov, P., Ganjali, Y.: Buffer Sizing Experiment at Facebook, 2019 Workshop on Buffer Sizing, Stanford University, Palo Alto CA USA, Article No. 9, pp. 1-6, 2019

[18]. Vu-Brugier, G., Stanojevic, R. S., Leith, D. J., Shorten, R. W.: “A Critique of Recently Proposed Buffer Sizing Strategies,” ACM Computer Communications Review, vol. 37, no. 1, pp. 43-47, May, 2007

[19]. Zhang, Y., Loguinov, D.: “ABS: Adaptive Buffer Sizing for Heterogeneous Networks,” Journal of Computer Networks, vol. 54, no. 14, pp. 2562-2574, October, 2010

[20]. Summers, J., Barford, P., Greenberg, A., Willinger, W.: “An SLA Perspective on the Router Buffer Sizing Problem,” ACM SIGMETRICS Performance Evaluation Review, vol. 35, no. 4, pp. 40-51, March, 2008

[21]. Ganjali, Y., Mckeown, N.: “Update on Buffer Sizing in Internet Routers,” ACM SIGCOMM Computer Communications Review, vol. 36, no. 5, pp. 67-70, October 2006

[22]. Agung Surya Maulana, Budi Yanto, and Fauzi Erwis, “Visualization of Sales Danalyser Data in Dashboard Form Google Data Studio,” *JOURNAL OF ICT APLICATIONS AND SYSTEM*, vol. 2, no. 2, 2023, doi: 10.56313/jictas.v2i2.270.

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